Digital Image Processing & Machine Vision

Lecture # 3

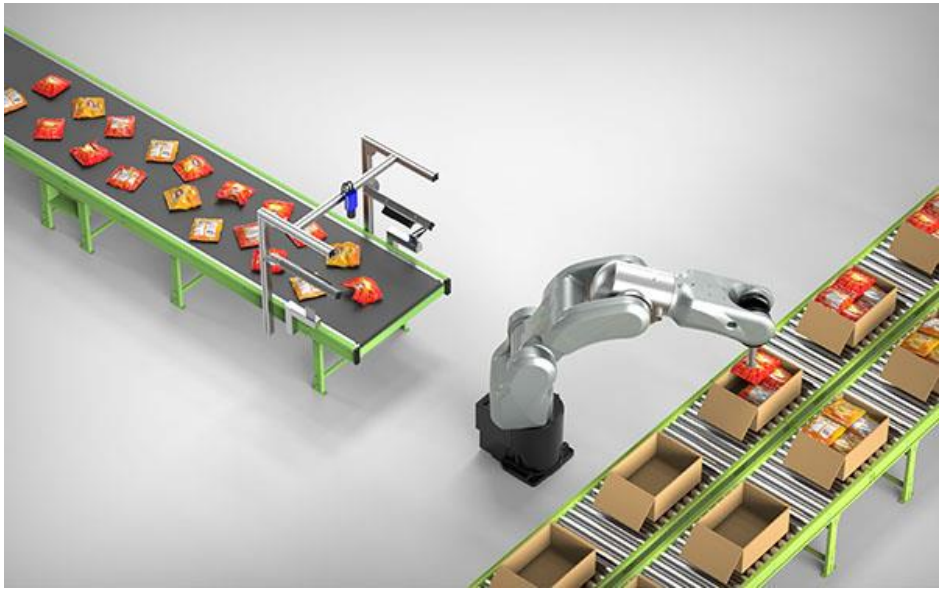
Instructed by

Dr. Abdul Rehman Abbasi

One picture is worth more than ten thousand words

QUIZ

Give at least 3 Reasons to justify a Machine Vision System over Human Operator?

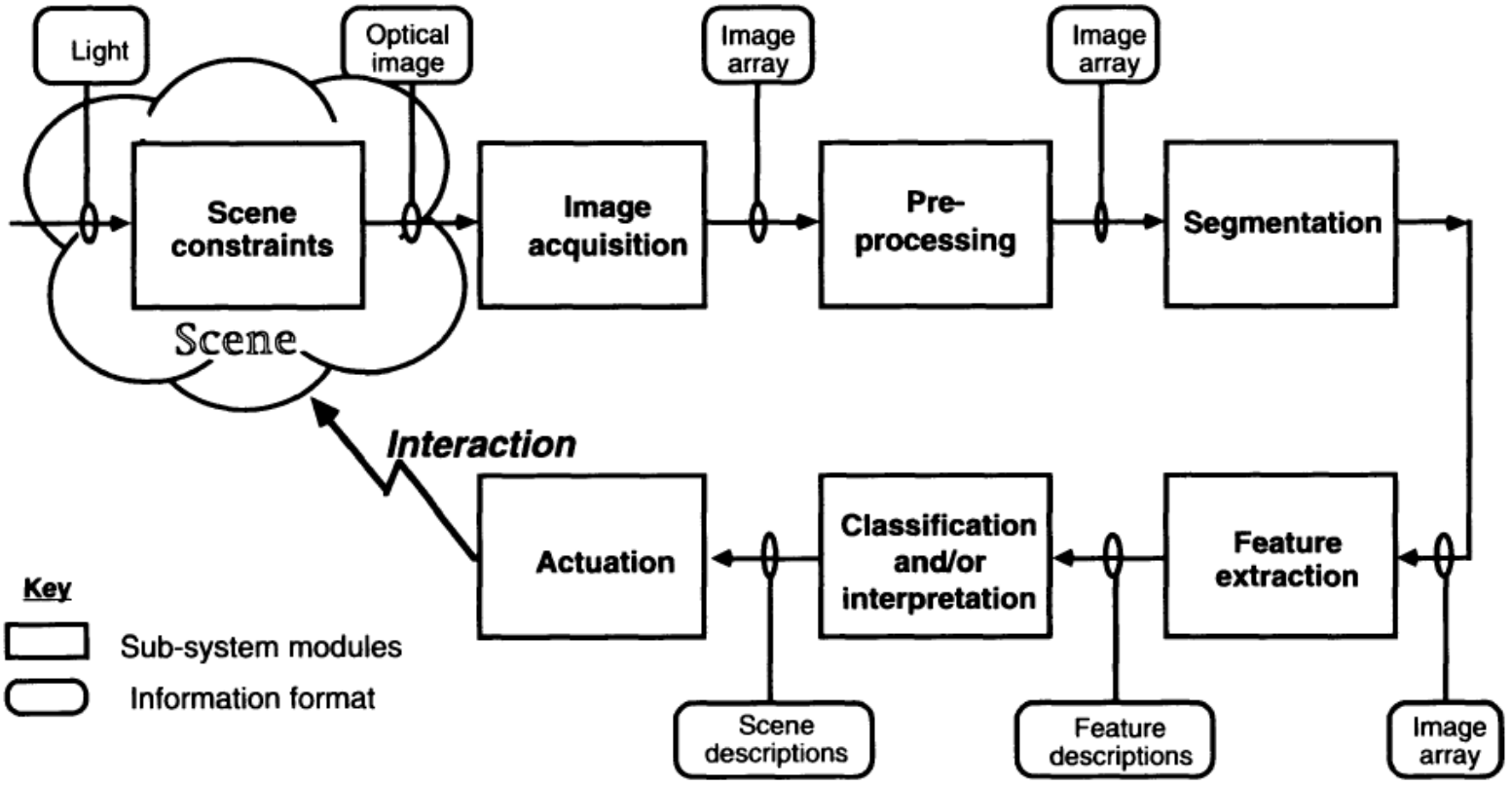


QUIZ

Give at least 3 Reasons to justify a Machine Vision System over Human Operator?

1. Humans are subjective . Vision systems can make measurements with greater objectivity and repeatability than humans.
2. Humans are fragile. Vision systems can be used in situations where humans would be uncomfortable or in danger.
3. Humans are fallible. Vision systems need never make a mistake through boredom or inattention.
4. Humans can be too slow. Vision systems can often operate in real-time relative to the manufacturing process, where humans cannot.
5. Humans can be insensitive to subtle change . Vision systems can observe such changes and react to them objectively .

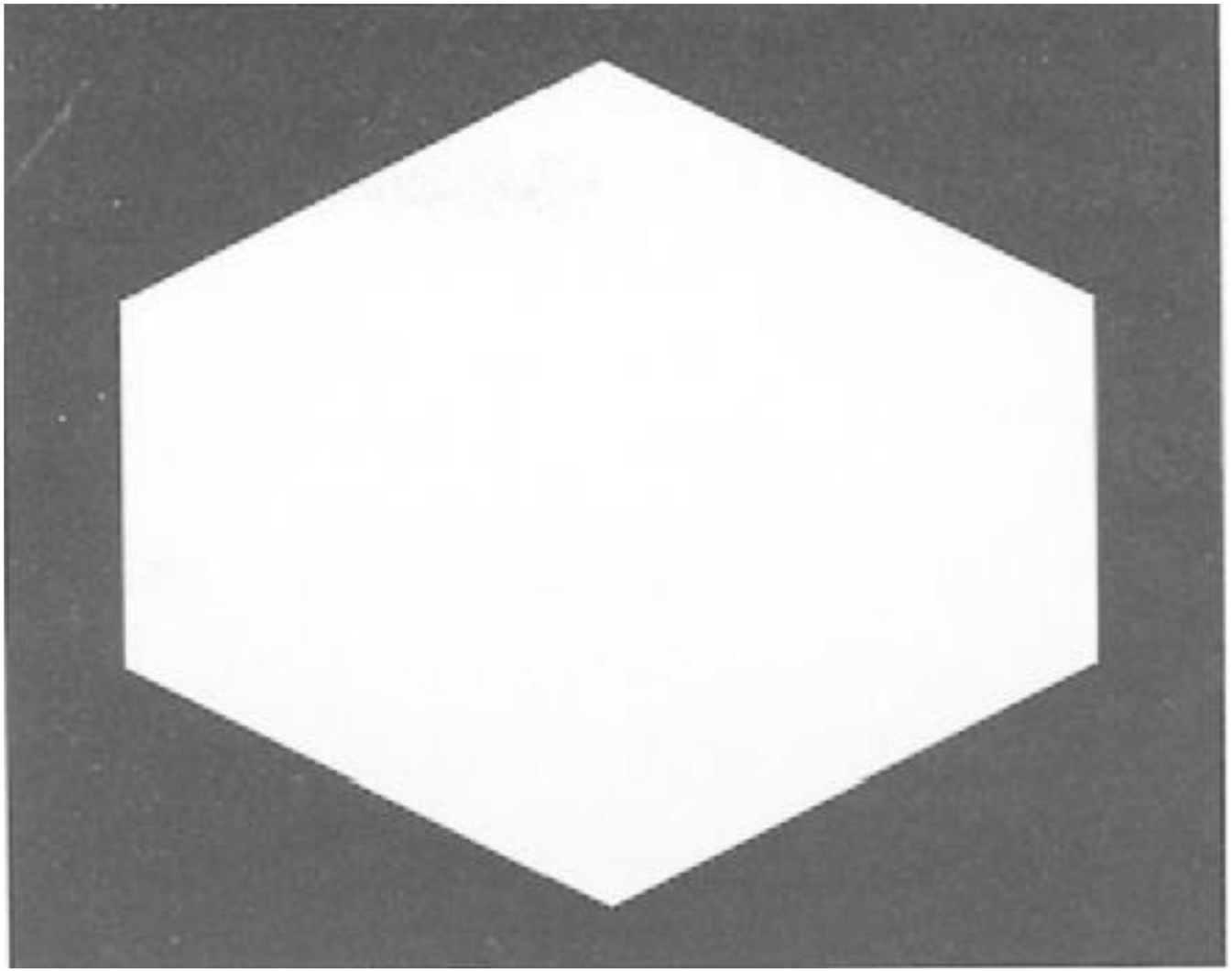
Generic Machine Vision Model



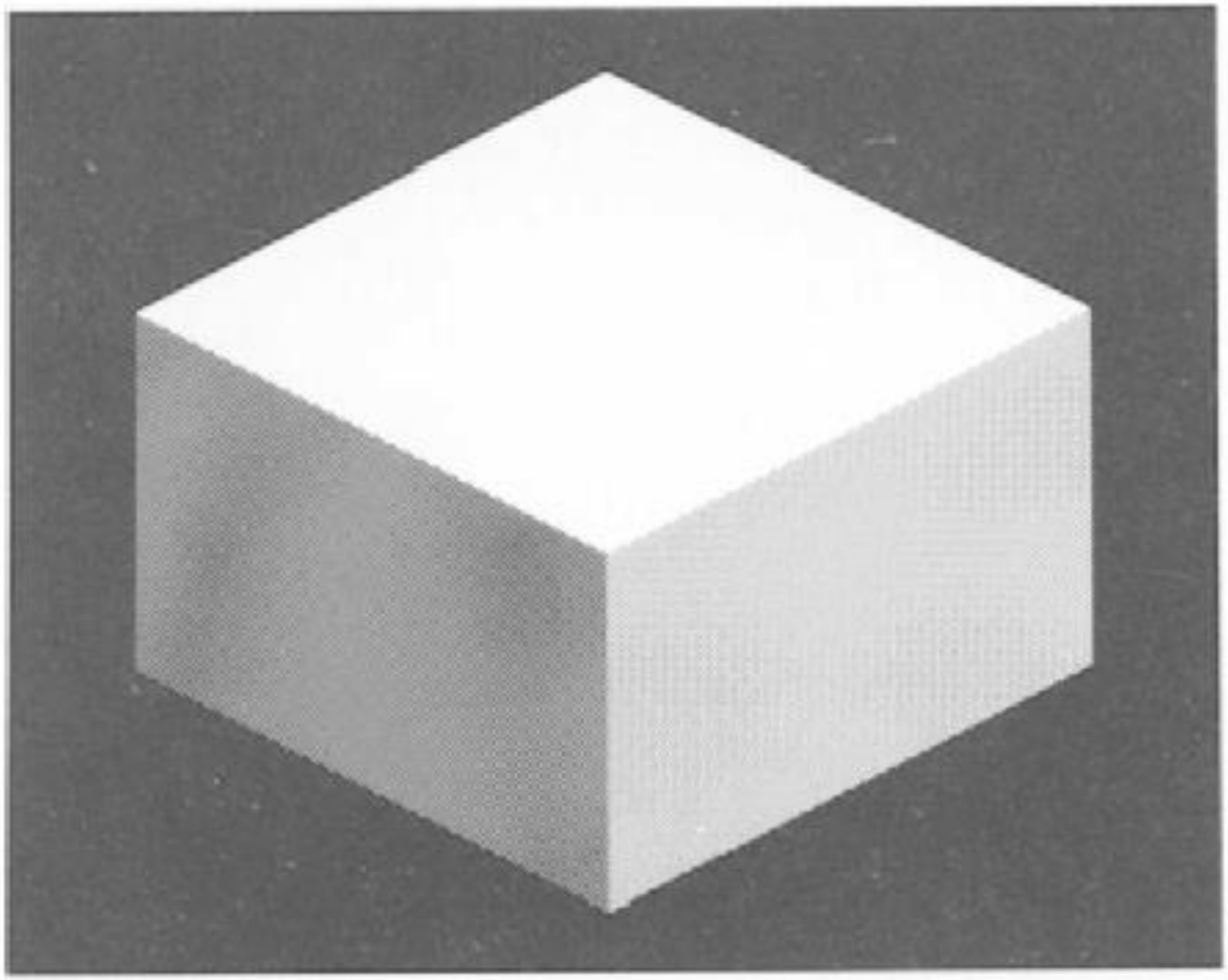
Generic Model of Machine Vision

- **Scene constraints**
- Image acquisition
- Preprocessing
- Segmentation
- Feature Extraction
- Classification and/or Interpretation
- Actuation

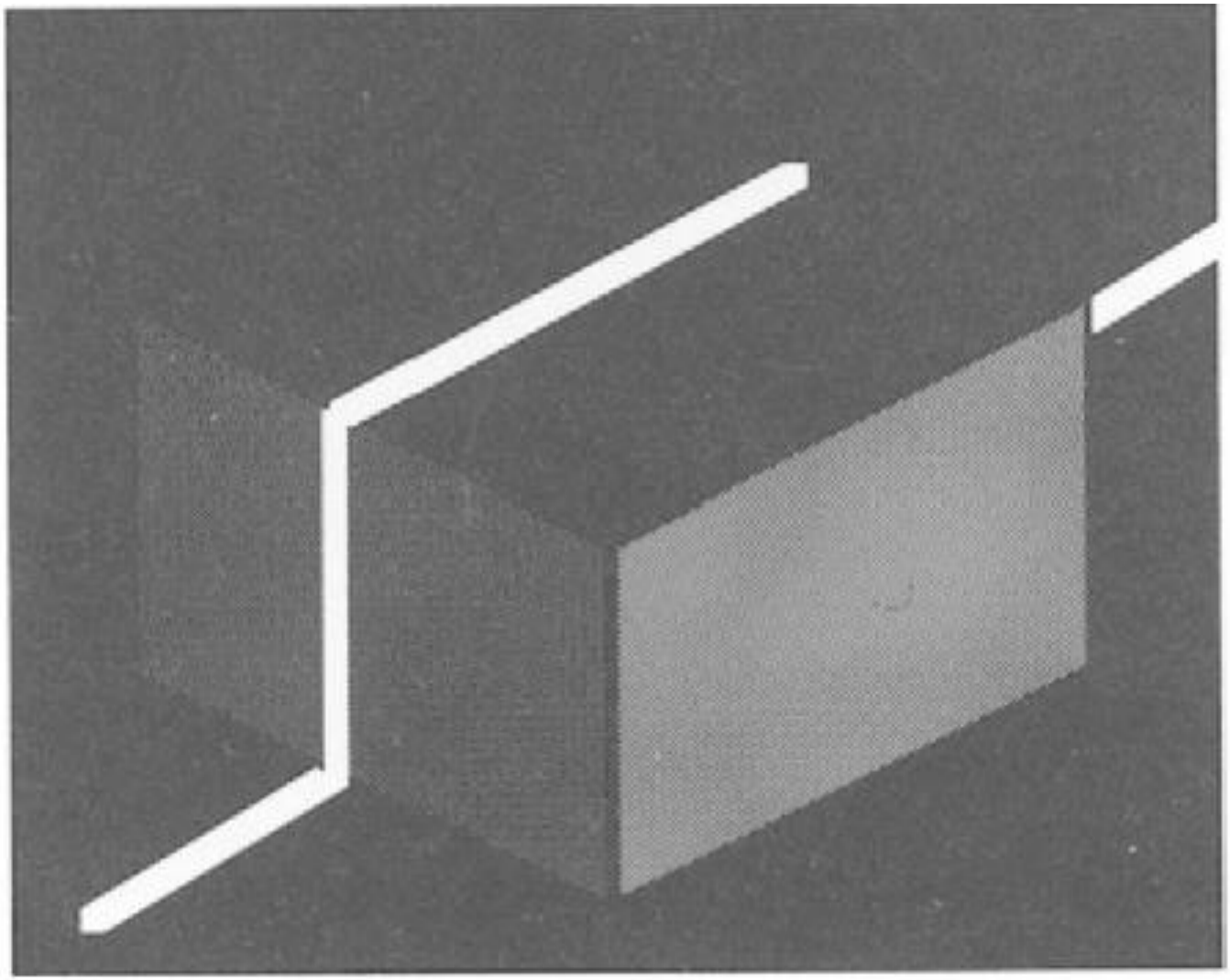
Cause of Degradation?



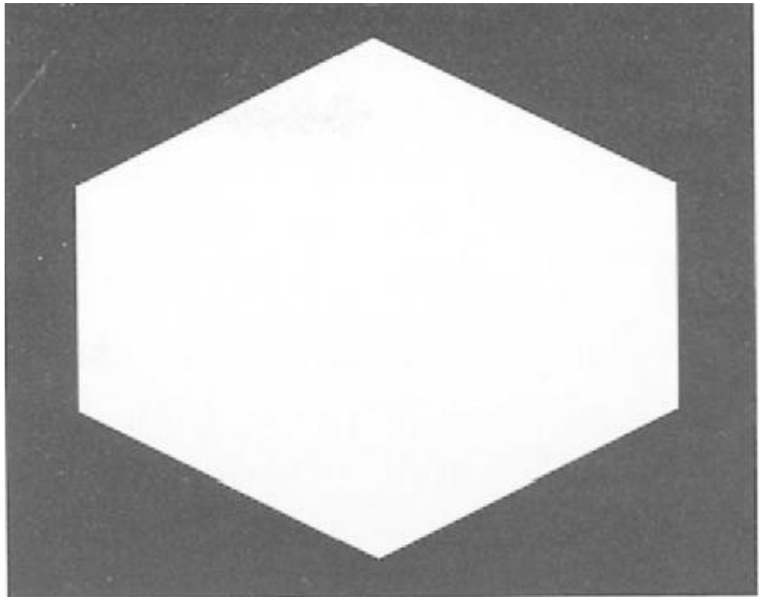
Shading Effects

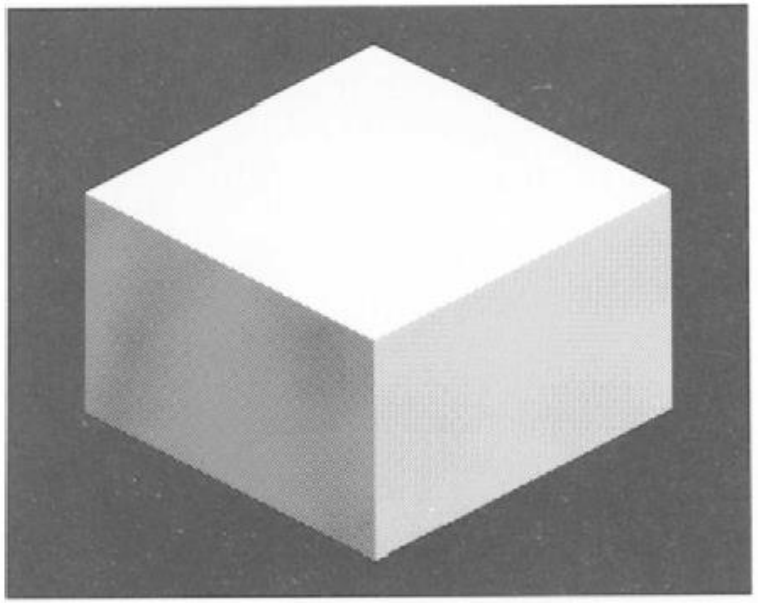


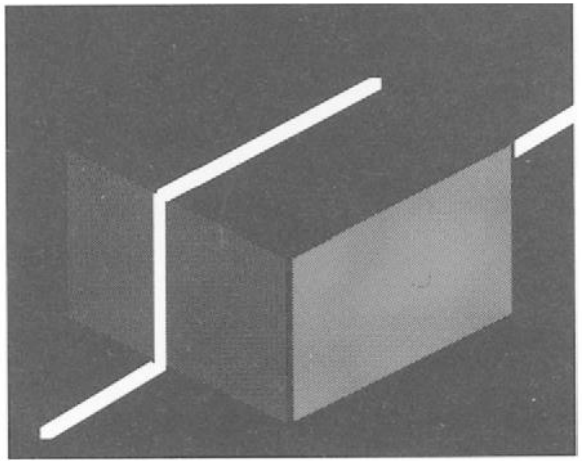
Structured Lighting gives Information about Depth



Scene Constraints: Effects of Light on Object







Scene Constraints

1. Scene refers to the environment in which the task is taking place and into which the machine -vision system is to be placed.
2. The aim of the scene constraint sub-system is to reduce the complexity of the subsequent subsystems to a manageable level. This is achieved by proper exploitation of a priori constraints such as: knowledge of limited number of objects possible in the scene, knowledge of their surface finish and appearance etc. We can also impose new constraints such as: replacement of ambient light with carefully controlled lighting.
3. As is clear from the terminology itself the Scene refers to the industrial environment in which the manufacturing is being done and the machine vision system is to perform the required task in that environment.
4. The aim of this module is to reduce the complexity of all the subsequent sub-systems to a manageable level which is achieved by exploitation of existing constraints and imposition of new ones.

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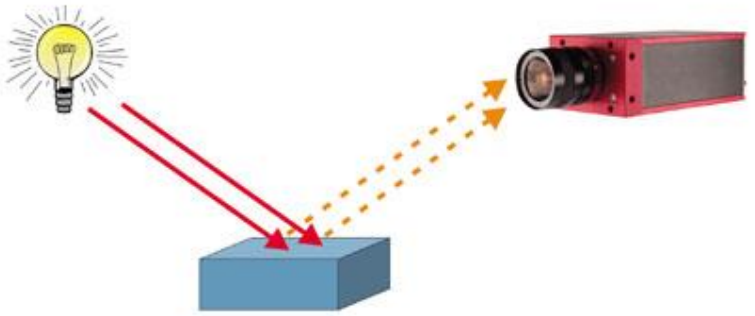
Scene Constraints

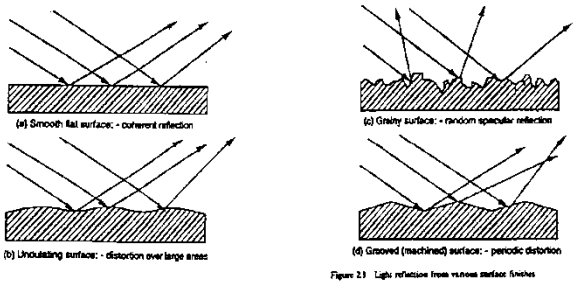
Two types of scene constraints can be applied

1. Inherent or natural constraints
2. Imposed constraints



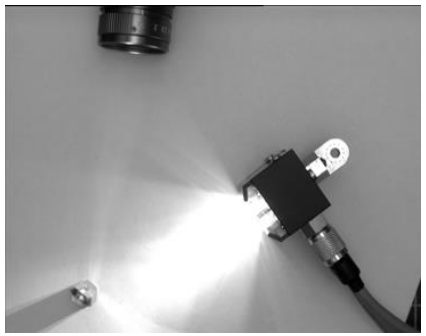
Inherent constraints

- Characteristics of the material
- Inherent features
- Limitations, in the range of objects
- Inherent positional limitations

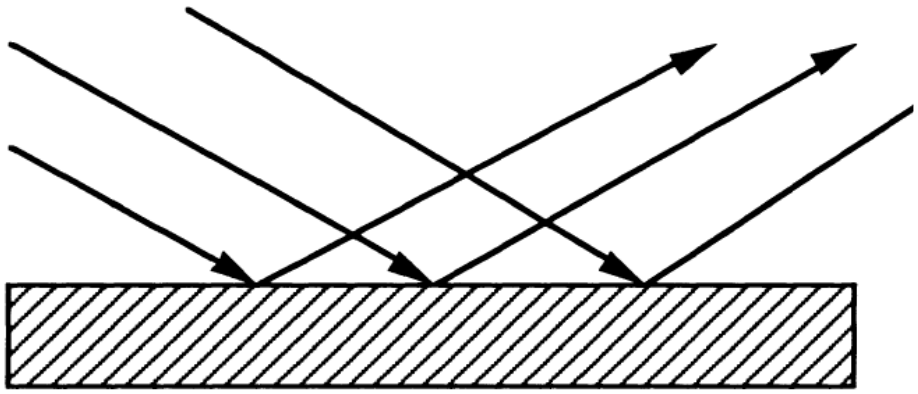

(a) Smooth flat surface: - coherent reflection
(c) Grainy surface: - random specular reflection
(b) Undulating surface: - distortion over large areas
(d) Grooved (machined) surface: - periodic distortion

Imposed constraints

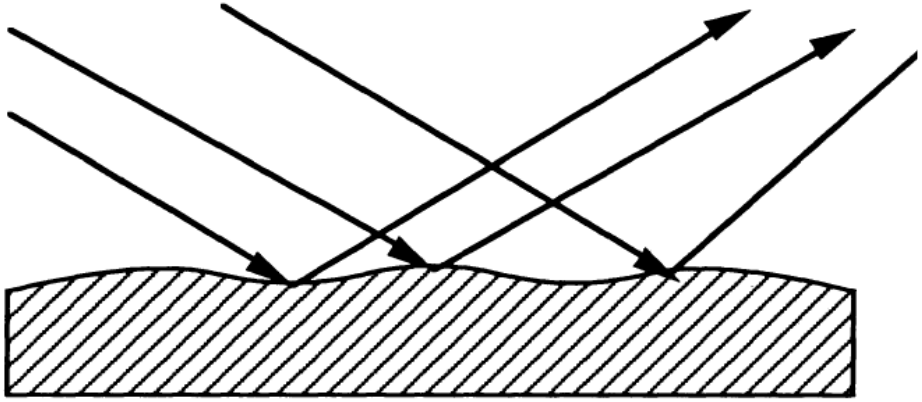
- Control of object features
- Control of object position
- Control of lighting conditions



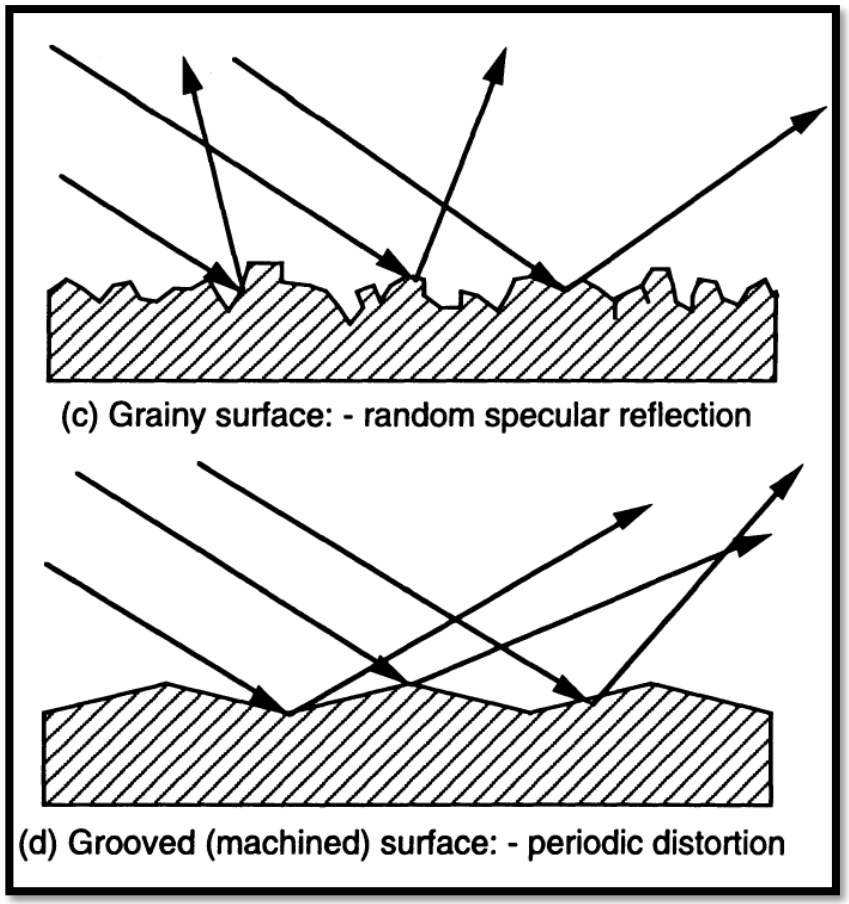
Characteristics of Material



(a) Smooth flat surface: - coherent reflection



(b) Undulating surface: - distortion over large areas



(c) Grainy surface: - random specular reflection

(d) Grooved (machined) surface: - periodic distortion

Inherent Features

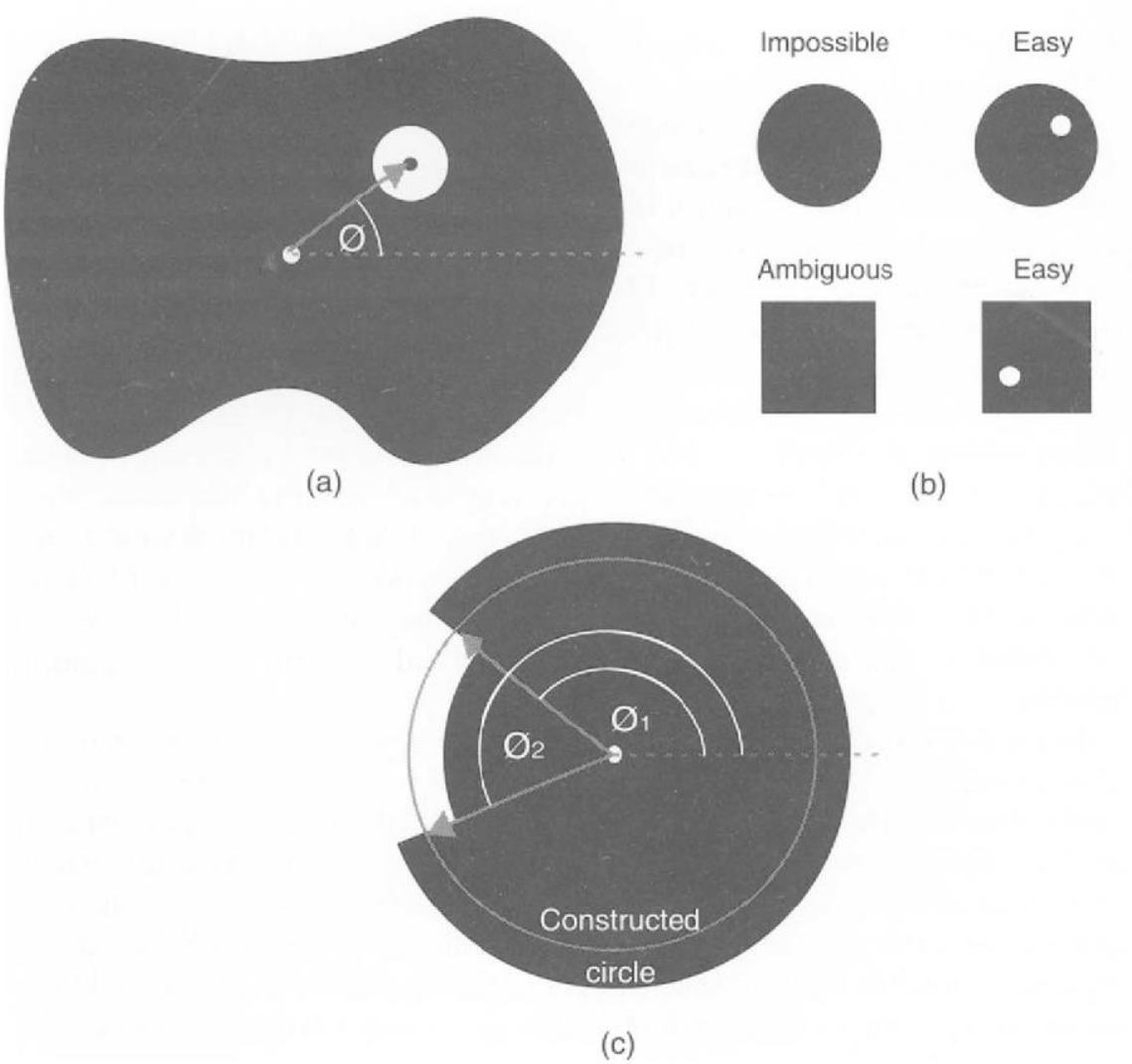


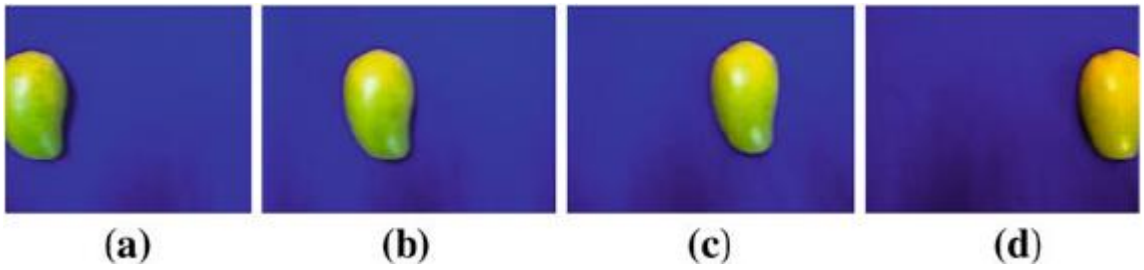
Figure 2.2 Orientation by inherent features: (a) object centroid/hole centroid method; (b) what a difference a hole makes!; (c) use of constructed circle, centred on object centroid. Note that in (c), the angle $(\phi_2 - \phi_1)$ is characteristic of the object outline (for a particular radius of constructed circle, in the general case) and thus the methods may be used in object recognition as well as orientation

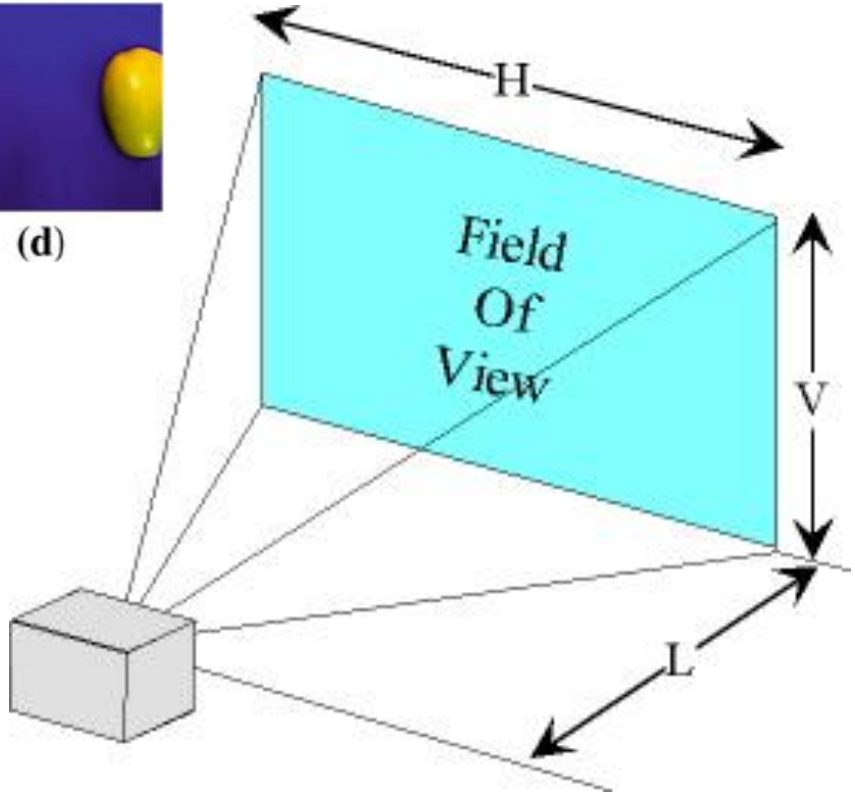
Limitations in the Range of Objects

- Optical character recognition (OCR) for printed English text is much simpler than for Chinese or Japanese text because there are only 26 letters and 10 numbers to be identified, rather than thousands of icons .
- In applications where only numbers are allowed the pattern recognition problem is considerably further simplified.

Inherent positional limitations

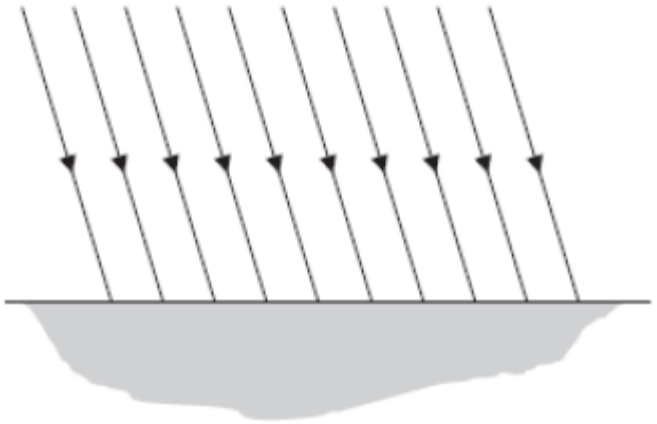
- Field of view (Conveyer belt operations)

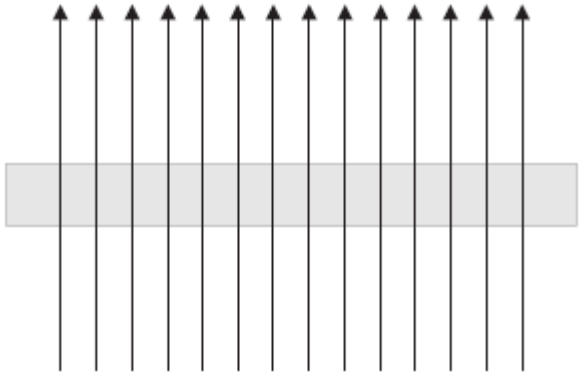




Control of Lighting Conditions-1

Directional Illumination





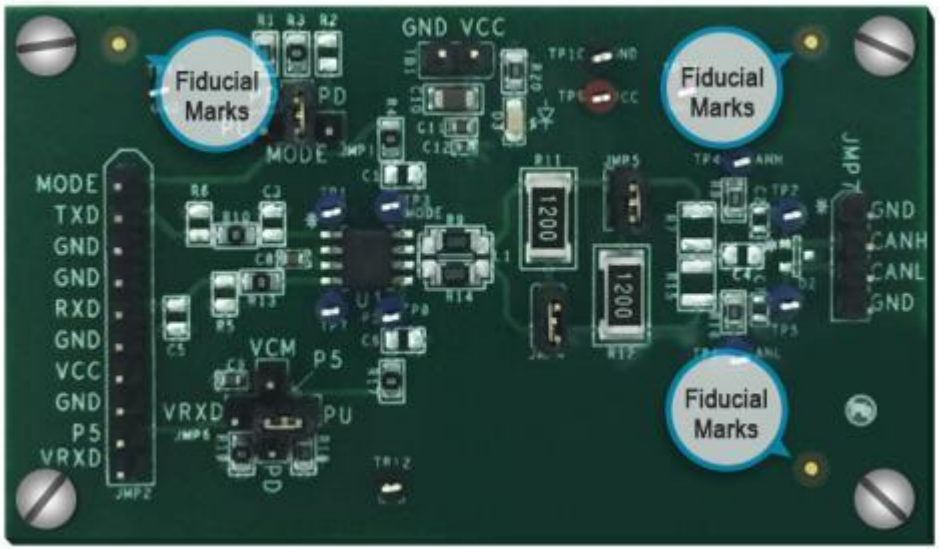
Rear or Back Illumination

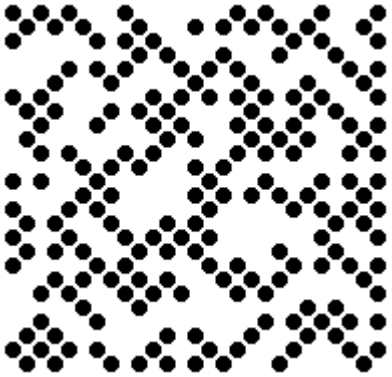
Control of Lighting Conditions-2

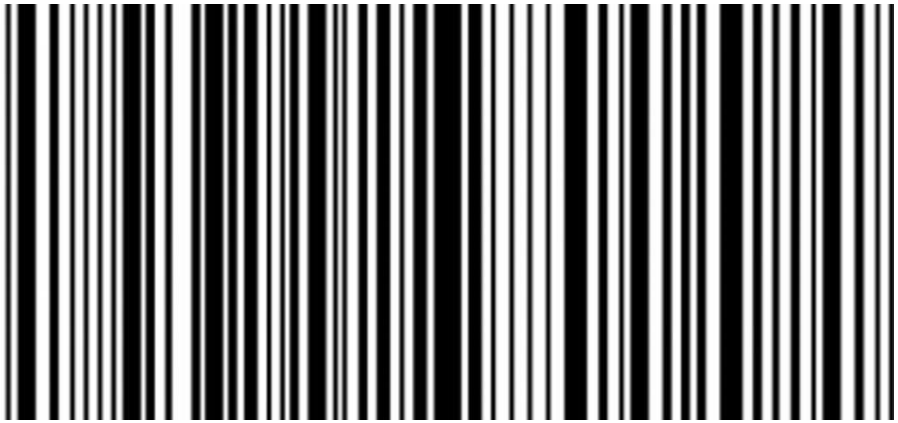
Directional (Front) Lighting

Rear (Back) Lighting

Control of Object Features





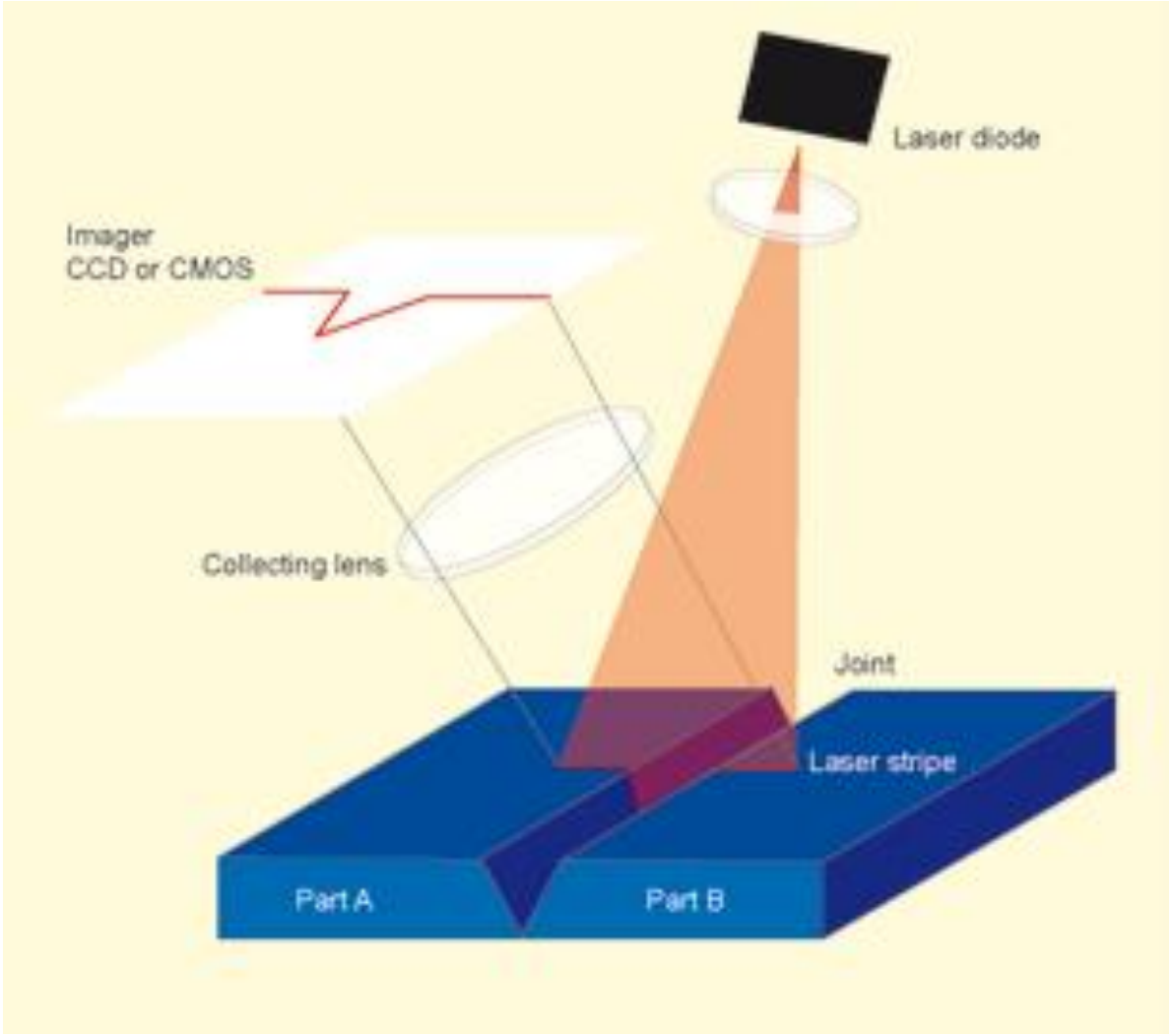


Lighting Sources

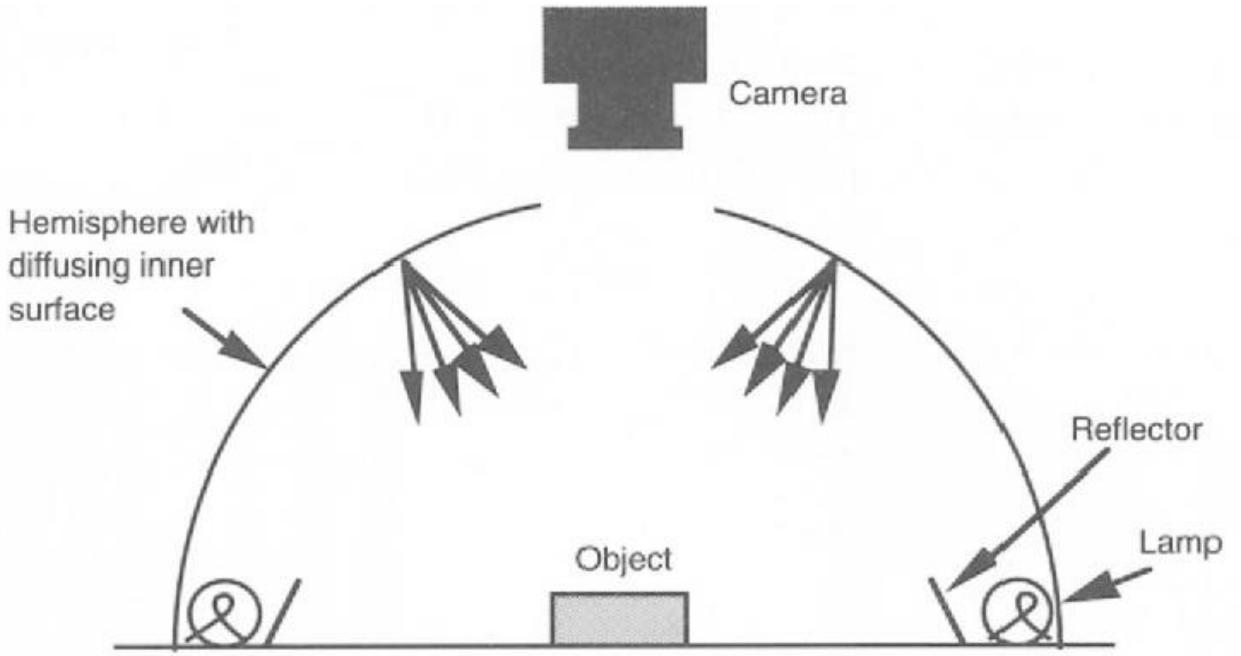
- LED illumination units
- Metal halide light sources (“cold light sources” transmitted over fibre-optic cables)
- Laser illumination units
- Fluorescent light (high-frequency)
- Halogen lamps

Light Source Type	Advantages	Disadvantages
LED Array of light-emitting diodes	Can form many configurations within the arrays; single color source can be useful in some application	Some features hard to see with single color source; large array required to light large area
Fiber-Optic Illuminators Incandescent lamp in housing; light carried by optical fiber bundle to application	Fiber bundles available in many configurations; heat and electrical power remote from application; easy access for lamp replacement	Incandescent lamp has low efficiency, especially for blue light
Fluorescent High-frequency tube or ring lamp	Diffuse source; wide or narrow spectral range available; lamps are efficient and long lived	Limited range of configurations; intensity control not available on some lamps
Strobe Xenon arc strobe lamp, with either direct or fiber bundle light delivery	Freezes rapidly moving parts; high peak illumination intensity	Requires precise timing of light source and image capture electronics. May require eye protection for persons working near the application

Laser Applications



Directional Illumination



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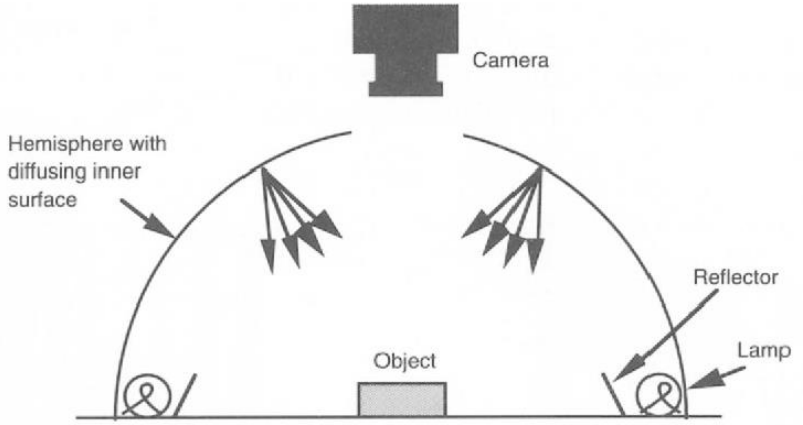

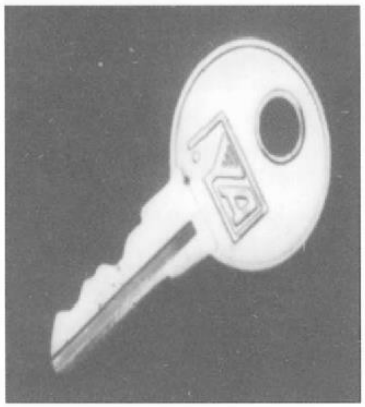

(b)

(c)

Figure 2.4 Diffuse omni-directional illumination: (a) implementation schematic; (b) key under directional illumination; (c) the same scene with uniform, diffuse, lighting

Directional Lighting

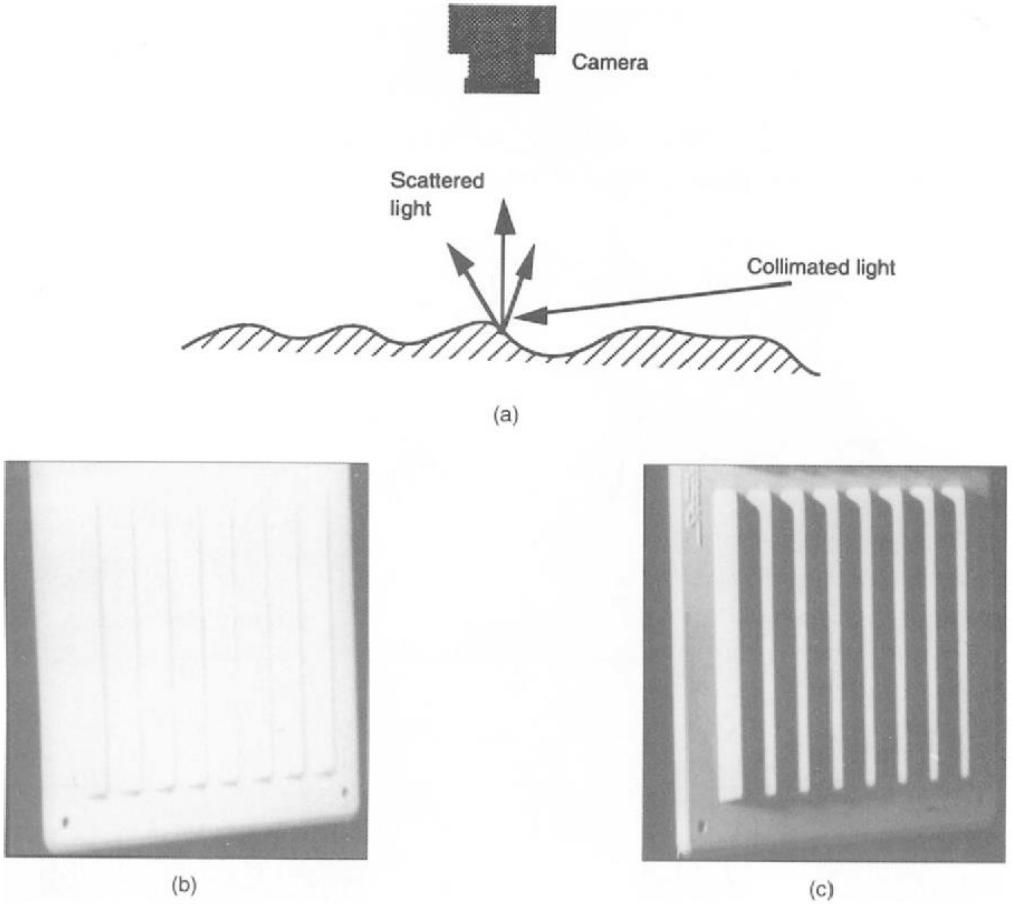

Figure 2.5 Directional lighting: (a) implementation schematic; (b) louvred surface with diffuse illumination; (c) the same scene under directional lighting

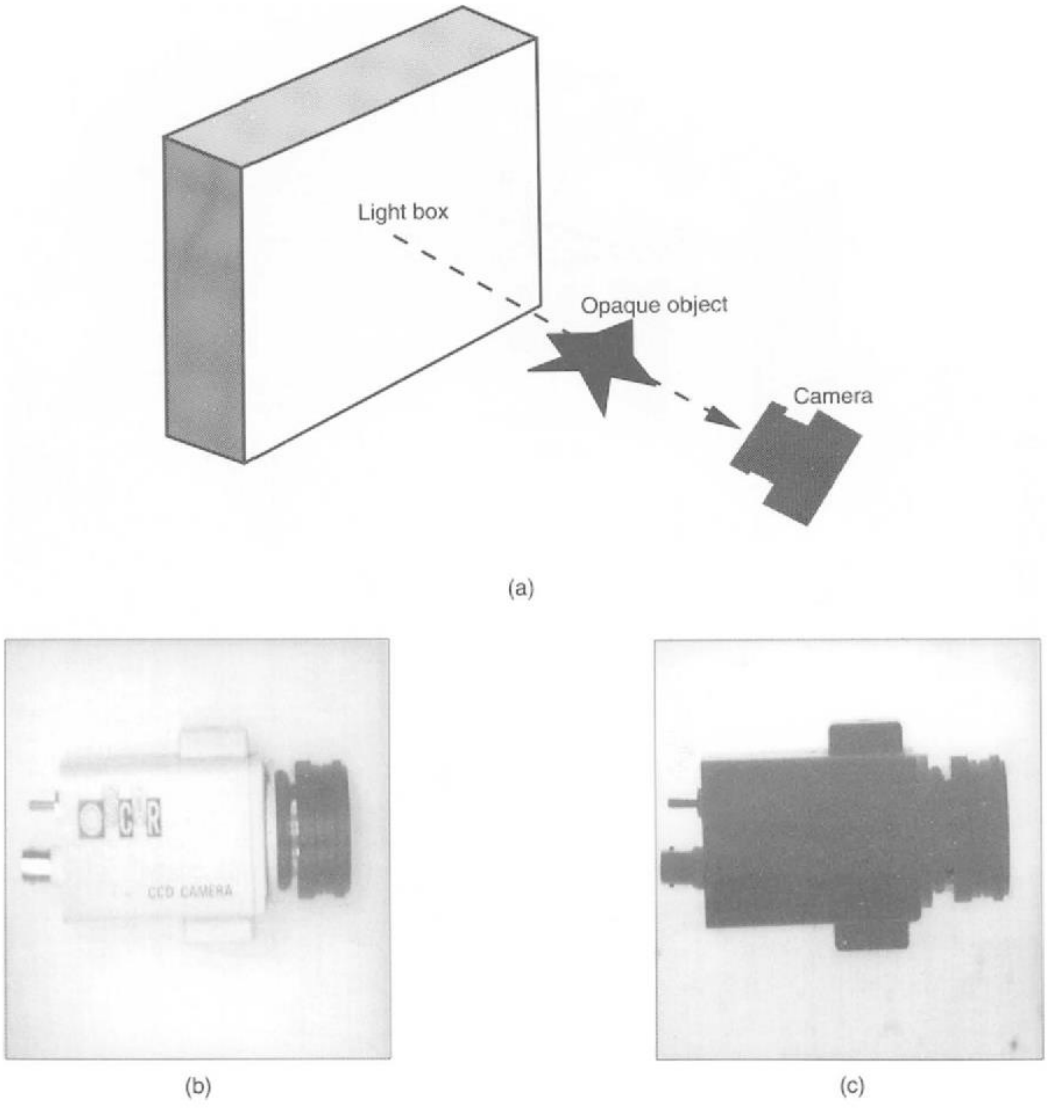

Figure 2.6 Light-field illumination: (a) implementation schematic; (b) scene under normal front-lighting conditions; (c) the same scene when back-lit. Note that in (c) all surface detail on the object is suppressed and a high contrast image which lends itself to thresholding to binary is produced. See also figure 4.8 in section 4.2.4.

Generic Model of Machine Vision

- Scene constraints
- Image acquisition
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Image Acquisition

- Translation from the light stimuli falling onto the photo sensors of a camera to a stored digital value within the computer's memory.
- Each digitized picture is typically of 512x512 pixels resolution, with each pixel representing a binary, grey or color value.
- To ensure that no useful information is lost a proper choice of spatial and luminescence resolution parameters must be made.
- Depending on particular application cameras with line scan or area scan elements can be made use of for image acquisition.

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Preprocessing

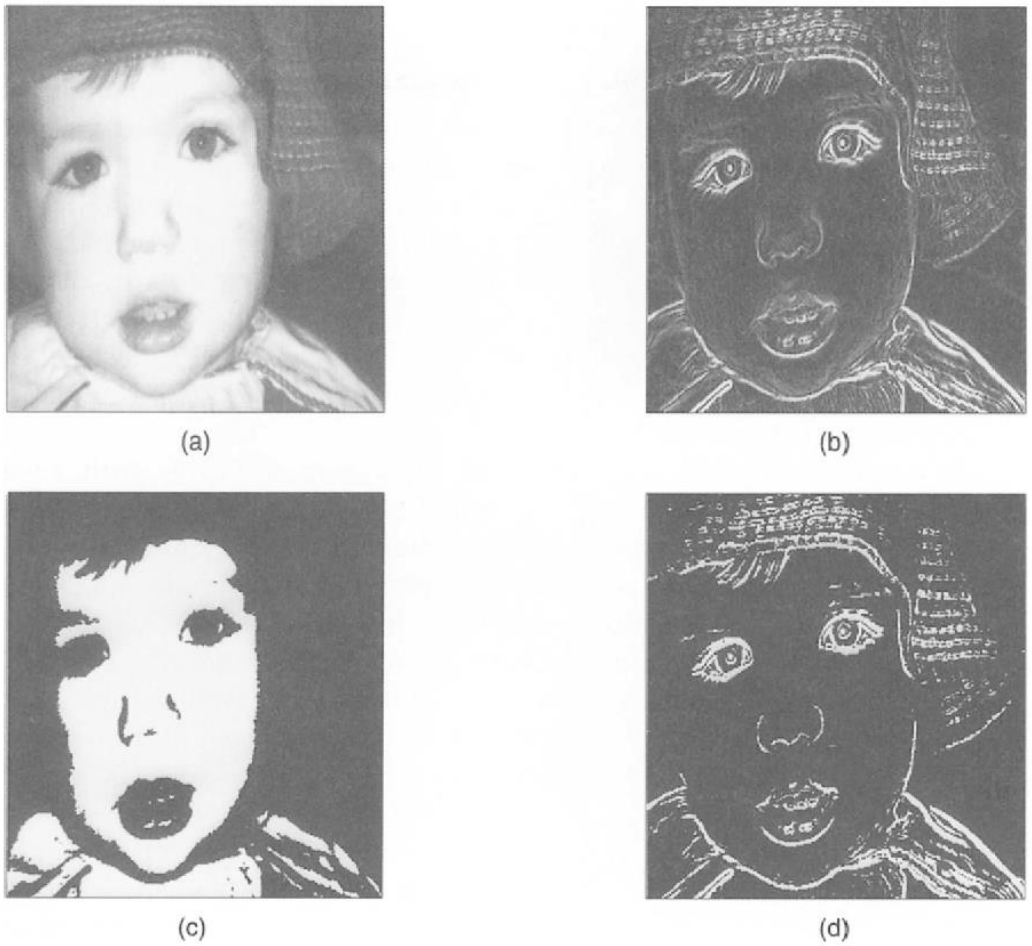

Figure 1.3 Preprocessing and segmentation operations: (a) original grey scale image ($512 \times 256 \times 6$ bits); (b) the Sobel algorithm used to edge-enhance (a); (c) binary version of (a) thresholded at grey level 47; (d) binary version of (b) thresholded at grey level 28

Preprocessing-1

- To produce a form of the acquired image which is better suited for further operations the processes (contrast enhancement, and adjustment, filtering to remove noise and improve quality) modify and prepare pixel values for digitized image.
- Fundamental information of the image is not changed during this module.
- The initially acquired image has direct pixel by pixel relation to the original scene and thus lies in the spatial domain.
- Transformations from spatial to frequency domain can be done using Fourier transforms, which is although not very computationally efficient operation.

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Preprocessing-2

- Low level processing for image improvement such as histogram manipulations (grey level shifting or equalization) involves noisy images clean up and highlight features of particular interest.
- With the use of some transformations, pixels are shared among grey levels which would enhance or alter the appearance of the image.
- Histogram manipulations provide simple image improvement operations, either by grey level shifting or, equalization.
- An image histogram is easily produced by recording the number of pixels at a particular grey level.
- If this shows a bias towards the lower intensity grey levels, then some transformation to achieve a more equitable sharing of pixels among the grey levels would enhance or alter the appearance of the image. Such transformations will simply enhance or suppress contrast, and stretch or compress grey levels, without any alteration in the structural information present in the image.

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- Histogram manipulations provide simple image improvement operations, either by grey level shifting or, equalization.
- An image histogram is easily produced by recording the number of pixels at a particular grey level.
- If this shows a bias towards the lower intensity grey levels, then some transformation to achieve a more equitable sharing of pixels among the grey levels would enhance or alter the appearance of the image. Such transformations will simply enhance or suppress contrast, and stretch or compress grey levels, without any alteration in the structural information present in the image.

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Preprocessing-3

- Another important class of spatial domain algorithms is designed to perform pixel transformation, whose final value is calculated as a function of a group of pixel values (or 'neighborhood') in some specified spatial location in the original image.
- Many filtering algorithms for smoothing (low pass) and edge enhancement (high pass) are firmly in this category.
- This introduces the basic principle of 'windowing operations' in which a 2-D (two-dimensional) mask, or window, defining the neighborhood of interest is moved across the image, taking each pixel in turn as the centre, and at each position the transformed value of the pixel of interest is calculated.

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Categories

- Four categories of image pre-processing methods according to the size of the pixel neighborhood that is used for the calculation of a new pixel brightness:
  - pixel brightness transformations,
  - geometric transformations,
  - pre-processing methods that use a local neighborhood of the processed pixel
  - Image restoration that requires knowledge about the entire image.

Neighborhood Operations

- A neighbourhood operation generates an 'output' pixel on the basis of the pixel at the corresponding position in the input image and *on the basis of its neighbouring, pixels.*
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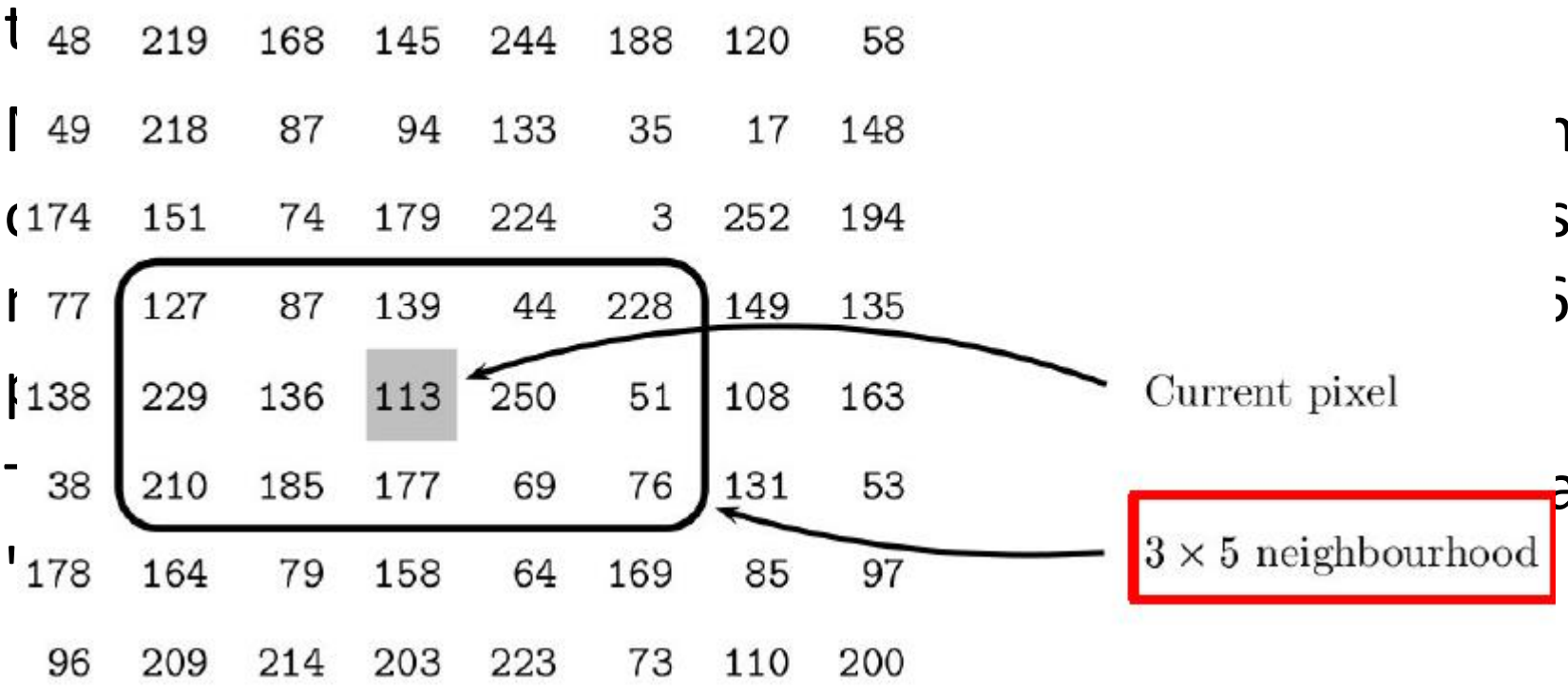

Image enhancement

-1	-1	-1
-1	9	-1
-1	-1	-1

1	1	1
1	1	1
1	1	1

1	0	-1
1	0	-1
1	0	-1

1	1	1
0	0	0
-1	-1	-1

Result

Low Pass Filter (5x5 median)